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**Fluid driven pumping apparatus.**

A fluid driven pumping apparatus comprises a housing (1) containing a twin rotor screw type positive displacement motor (10) and a twin rotor screw type positive displacement pump (11). The screw rotors of said pump (11A,11B) and motor (10A,10B) are mounted on a pair of common shafts (13,14).

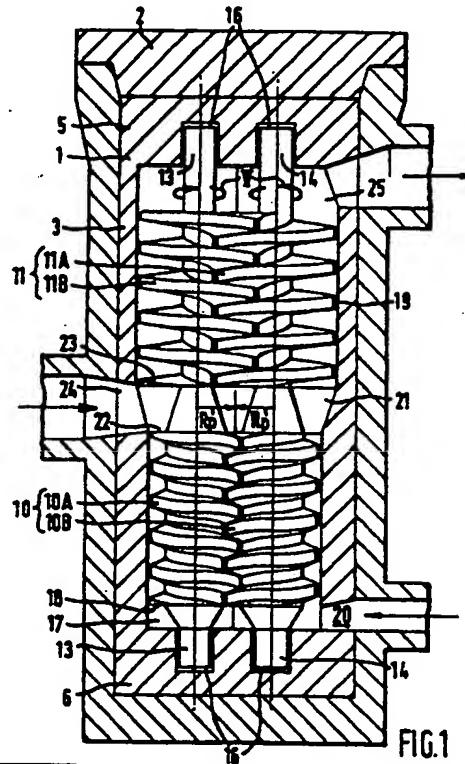


FIG.1

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## FLUID DRIVEN PUMPING APPARATUS

The invention relates to a fluid driven apparatus for pumping a fluid or a mixture of fluids. The invention relates in particular to a fluid driven apparatus for pumping fluids at remote or difficult accessible locations, such as in a well or in a sub-sea flowline.

Apart from jet pumps, which are rather inefficient, presently available fluid driven pumps are generally of the turbine type. However, turbine pumps employ high fluid velocities and narrow fluid passages which gives rise to a high wear rate and thus to frequent maintenance if the produced fluid is sand bearing.

An object of the invention is to provide a compact and reliable fluid driven pumping apparatus which has a low wear rate even if the produced fluid is sand bearing and which can be easily installed in a flowline system.

A further object of the invention is to provide a fluid driven pumping apparatus which is able to pump both gaseous and liquid fluids or mixtures thereof.

The pumping apparatus according to the invention thereto comprises a twin rotor screw type positive displacement motor having a driving fluid inlet and a driving fluid outlet and connected to said motor a twin rotor screw type positive displacement pump having a pumped fluid inlet and a pumped fluid outlet. The apparatus further comprises a pair of shafts rotatably mounted in a housing, each shaft carrying a screw rotor of said pump and a screw rotor of said motor.

In a preferred embodiment of the invention the driving fluid outlet is in fluid communication with the pumped fluid inlet so that the driving fluid emerging from the motor mixes with the incoming pumped fluid before the combined fluid stream passes into the pump.

In a suitable embodiment of the invention the screw rotors of said pump and motor which are mounted on a common shaft are identical in helix angle and pitch diameter. However, the screw rotors of said pump preferably have a larger tip diameter and a correspondingly smaller base diameter than the screw rotors of said motor.

The invention will now be described by way of example with reference to the accompanying drawing, in which:

Fig. 1 shows a longitudinal section of a pumping apparatus according to the invention.

Fig. 2 shows a longitudinal section of another pumping apparatus according to the invention.

Fig. 3 is a longitudinal section of the apparatus of Fig. 2 taken along line I-I in Fig. 2 and seen in the direction of arrows III.

Fig. 4 is a cross-section of the apparatus of Fig. 2 and 3 seen in the direction of arrows IV in Fig. 3.

The pumping apparatus shown in Fig. 1 comprises a housing 1 enclosed in a protective shell 2. The housing 1 consists of a side wall 3 and upper and lower terminal walls 5 and 6, respectively. The lower part of the housing contains a motor section consisting of a twin rotor screw type positive displacement motor 10, whereas the upper part of the housing contains a pump section consisting of a twin rotor screw type positive displacement pump 11. The motor section 10 comprises a pair of cooperating screw rotors 10A and 10B, and the pump section 11 comprises a similar pair of cooperating screw rotors 11A and 11B. The screw rotors 10A and 11A shown at the left side of the drawing are identical in helix angle and they are mounted on a common shaft 13, whereas the screw rotors 10B and 11B shown at the right side of the drawing are also identical in helix angle and mounted on a common shaft 14. The helix angles of the cooperating pairs of screw rotors 10A, 10B and 11A, 11B, respectively, are opposite to each other and the axes of rotation of the shafts 13 and 14 are parallel to each other.

As illustrated in Fig. 1 the screw rotors 11A, 11B of the pump and the screw rotors 10A, 10B of the motor have identical pitch radii  $R_p$ , but the screw rotors 11A, 11B of the pump have a larger tip radius and a correspondingly smaller base radius than the screw rotors 10A, 10B of the motor.

The shafts 13 and 14 are supported by bearings 16 in the upper and lower terminal walls 5, 6.

The bearings 16 may be of any suitable type and it is preferred to lubricate the bearings with clean drive fluid derived from an inlet compartment 17 at the upstream end 18 of the motor. In order to facilitate lubrication of the bearings 16 in the upper terminal wall 5 the shafts 13 and 14 may each be provided with a bore (not shown) forming a fluid communication between the said inlet compartment 17 and the bearings 16 in said upper wall 5.

Furthermore, by means of radial drillings (not shown) in the screw rotors 11A, 11B, communicating with the bores, clean drive fluid can be introduced into close clearance points at the rotor tips, further preventing damage by sand and other erosive matter. Alternatively, clean drive fluid can be supplied to the bearings 16 in the upper terminal wall 5 through a suitable passage (not shown) in the housing.

During operation of the pumping apparatus driving fluid is injected into the inlet compartment 17 via a driving fluid inlet port 20 passing through the side wall 2 of the apparatus at a location adjacent to the lower housing wall 6. Said injection causes the drive fluid to move in upward direction through the lower compartment 8 towards a chamber 21 formed in the middle of the housing 1 between the downstream end 22 of the motor 10 and the upstream end 23 of the pump, thereby actuating the screw rotors 10A, 10B of the motor to rotate in opposite directions, as indicated by arrows V. The manner in which the drive fluid actuates the screw rotors 10A, 10B of the twin rotor screw type motor is known per se and does not require a detailed description.

Said rotation of the screw rotors 10A, 10B of the motor 10 induces the shafts 13, 14 and thus the screw rotors 11A, 11B of the pump 11 to rotate at the same speed in the direction of arrows V. Due to the large tip diameter and small base diameter of the pump rotors 11A, 11B in comparison to the motor rotors 10A, 10B, or in other words due to the large displacement volume of the pump 11 in comparison to that of the motor 10, the pump rotors 11A, 11B tend to suck more fluid away from the chamber 21 than the amount of driving fluid discharged from the motor 10.

This causes pumped fluid to be sucked into the chamber via a production fluid inlet 24 formed in the side wall 3 of the housing and to be subsequently pumped together with the driving fluid in upward direction by the pump rotors 11A, 11B towards a pumped fluid outlet 25 formed near the upper terminal wall 5.

The pumping apparatus shown in Fig. 1 may be used to pump single-or multiphase fluids such as mixture of hydrocarbon fluids containing crude oil and natural gas, while the pumped fluids may contain solid particles, such as sand, without giving rise to a largely increased wear rate of the apparatus. If the pumped fluid mainly consists of a liquid, it is preferred to use recirculated pumped fluid as driving fluid and to filter solid particles such as sand from the pumped fluid before reinjecting it into the driving fluid inlet 20 of the apparatus as a clean driving fluid. The reinjected pumped fluid may be mixed up with other fluids or lubricants if the viscosity of the pumped fluid is too high to allow it to be used as driving fluid.

If the pumped fluid consists of a gas-liquid mixture it is preferred to separate the liquid phase from the gaseous phase and to use the liquid phase as driving fluid. If the pumped fluid mainly consists of a gas it is preferred to use a liquid as driving fluid. This would enable sufficient lubrication

of the bearings 16 and rotor tips 19 and would further provide sufficient minimum flow of liquid through the pump to enable the pump to continue to develop its full differential pressure.

It will be appreciated by those skilled in the art that instead of arranging the shafts parallel to each other as shown in Fig. 1, the shafts may also be arranged at an angle relative to each other, provided that the screw rotors of the pump and motor have a suitable shape.

The pumping apparatus shown in Figures 2-4 comprises a housing 31 with a longitudinal axis I-I and a side wall 32 having a cylindrical outer surface 33 arranged co-axial to said axis I-I. On the outer surface 33 of the side wall 32 there are mounted two inflatable packers 34 or other suitable devices for securing the apparatus at a selected downhole location inside a production string (not shown) within a well from which a fluid, such as crude oil, is produced. The housing 31 further comprises upper and lower terminal walls 35 and 36, respectively, and an intermediate wall 37, which walls are substantially flat and arranged cross-axial to the longitudinal axis I-I. The intermediate wall 37 is located in the middle of the housing 31 and divides the housing interior into an upper compartment 38 and a lower compartment 39. The upper housing compartment 38 comprises the motor section consisting of a twin rotor screw type positive displacement motor 40, whereas the lower housing compartment 39 comprises the pump section consisting of a twin rotor screw type positive displacement pump 41. The motor section 40 comprises a pair of cooperating screw rotors 40A and 40B, and the pump section 41 comprises a similar pair of cooperating screw rotors 41A and 41B. The screw rotors 40A and 41A shown at the left side of Fig. 2 are identical in diameter and helix angle and they are mounted on a common shaft 43, whereas the screw rotors 40B and 41B shown at the right side of Fig. 2 are also identical in diameter and helix angle and mounted on a common shaft 44. The helix angles of the cooperating pairs of screw rotors 40A, 40B and 41A, 41B, respectively, are opposite to each other and the axes of rotation of the shafts 43 and 44 are parallel to each other and to the longitudinal axis I-I.

The shafts 43 and 44 are supported by bearings 46 in the upper and lower terminal walls 35, 36 and pierce through openings 47 in the intermediate wall 37. The openings 47 may be provided with sealing rings (not shown) to avoid fluid leakage between the upper and lower compartment 38 and 39 and they further may comprise a bearing assembly (not shown) for laterally supporting the shafts 43, 44.

The bearing assembly and the bearings 46 may be of any suitable type and it is preferred to lubricate the bearings with clean drive fluid derived from the upper-motor-compartment 38. In order to facilitate lubrication of the bearings 46 in the lower terminal wall 36 the shafts 43 and 44 are each provided with a bore 48 forming a fluid communication between the upper compartment 38 and the bearings 46 in said lower wall 36. Alternatively clean drive fluid can be supplied to the lower bearings 46 through a suitable passage (not shown) in the housing. Furthermore, by means of drillings (not shown) in the screw rotors 41A, 41B, communicating with the bores 48, clean drive fluid can be introduced into close clearance points at the rotor tips, further preventing damage by sand and other erosive matter.

As the pairs of screw rotors 40A, 41A and 40B, 41B mounted on each shaft 43, 44 are identical in diameter and helix angle, the axial thrusts are inherently in balance thus avoiding a substantial thrust bearing on the shafts 43, 44.

During normal operation of the pumping apparatus in a well, driving fluid is injected into the upper compartment 38 via a driving fluid inlet port 50 passing through the side wall 32 of the apparatus 31 at a location immediately above the intermediate wall 37. Said injection causes the drive fluid to move in upward direction through the upper compartment 38 towards a pair of driving fluid outlet ports 52 in the upper terminal wall 35, thereby actuating the screw rotors 40A, 40B of the motor, and simultaneously the shafts 43, 44 and screw rotors 41A, 41B, to rotate in opposite directions, as indicated by arrows VI. The manner in which the drive fluid actuates the screw rotors 40A, 40B of the twin rotor screw type motor is known per se and does not require a detailed description.

Said rotation of the screw rotors 41A, 41B of the screw pump 41 induces well fluid to be sucked into the lower compartment 39 via a pair of production fluid inlets 54 in the lower terminal wall 36 and to be subsequently pumped in upward direction through the lower compartment towards a production fluid outlet consisting of a conduit 55 discharging into the interior of the production tubing section (not shown) above the upper terminal wall 35. As illustrated in Fig. 3 and 4 the conduit 55 forms a by-pass along the upper compartment 38 of the apparatus and comprises a radial section 55A which is in fluid communication with the section of the interior of the lower compartment 39 adjacent to the intermediate wall 37 and an axial section 55B extending through a longitudinal bore in the side wall 31 of the housing.

The apparatus is installed in a production tubing (not shown) of a well in the following manner. The apparatus is connected to a wireline tool and lowered through the tubing to a selected depth where an opening has been shot through the tubing wall, which opening forms a fluid passage from an annular space surrounding the tubing and the tubing interior. The apparatus is subsequently anchored to the tubing wall by inflating the packers 34 on the side wall 32 thereof after checking that said opening in the tubing wall is located between the packers 34. In this manner the driving fluid inlet 50 is brought in fluid communication with the annular space around the tubing, while the apparatus divides the interior of the tubing in a lower tubing section extending between the well production zone and the lower terminal wall 36 of the apparatus and an upper tubing section extending from the upper terminal wall 35 of the apparatus towards the wellhead. Alternatively the apparatus may be located and supported in the production tubing by allowing it to rest on suitably located projections arranged in the base of the said tubing.

After having thus installed the apparatus in the well tubing the apparatus is disconnected from the wireline tool and pumping is started by injecting a drive fluid by pumping means located at the well head via the annular space and said opening in the tubing wall into the driving fluid inlet 50, thereby activating the screw rotors 40A, 40B of the motor section 40 to rotate the shafts and the screw rotors 41A, 41B of the pump section 41 in the directions illustrated by arrows VI. As described hereinbefore, said rotation causes the screw rotors 41A, 41B of the pump section 41 to suck the well fluids from the lower tubing section via the production fluid inlet ports 54 into the lower compartment 39 and to subsequently pump the well fluids in upward direction via the production fluid outlet 55 into the upper tubing section located above the apparatus 31. In the upper tubing section the production fluid is mixed with the drive fluid and transferred to the wellhead. It is preferred to use recirculated production fluid as driving fluid and to filter solid particles such as sand from the production fluid before reinjecting it into the well as a clean driving fluid. The reinjected production fluid may be mixed up with other fluids such as gasoline if the viscosity of the produced fluid is too high to allow it to be used as driving fluid. If the produced fluid is not suitable to be used as driving fluid then the driving fluid should not be mixed up with the production fluid in the production string, but should be transferred back to the wellhead via a separate return conduit connected to the driving fluid outlet 51 of the apparatus and located in the interior of the production tubing. Moreover, instead of using the well annulus as conduit for injecting driving fluid, a

separate supply conduit may be installed in the production tubing to supply the driving fluid to the apparatus. In this manner a closed circuit can be created through which drive fluid is circulated from the pumping means at the wellhead to the down-hole pumping apparatus and vice versa. The driving fluid supply and exhaust conduits that form the circuit may be suspended within the production tubing as a pair of co-axial pipes.

As illustrated in Figures 3 and 4 the apparatus is provided with a longitudinal passage 60 to enable lowering and raising of wireline tools through the production tubing to the production zone while the apparatus 31 is present inside the tubing. The longitudinal passage 60 extends through a bore in the side wall 32 of the apparatus and is provided near the upper end thereof with a plug 61 which can be removed when a wireline tool is lowered through the tubing. If desired, the removable plug 61 may be replaced by a valve (not shown) which is normally open but closes automatically if the apparatus is activated to pump well fluids to the surface.

The pumping apparatus according to the invention may be used to pump single or multiphase fluids such as mixture of hydrocarbon fluids containing crude oil and natural gas, while the produced fluids may contain solid particles, such as sand, without giving rise to a largely increased wear rate of the apparatus.

#### Claims

1. Fluid driven pumping apparatus comprising a twin rotor screw type positive displacement motor having a driving fluid inlet and a driving fluid outlet, and connected to said motor a twin rotor screw type positive displacement pump having a pumped fluid inlet and a pumped fluid outlet, the apparatus further comprising a pair of shafts rotatably mounted in a housing, each shaft carrying a screw rotor of said pump and a screw rotor of said motor.

2. The apparatus of claim 1, wherein the fluid displacement volume of said pump is larger than the fluid displacement volume of said motor.

3. The apparatus of claim 2, wherein said shafts are parallel to each other and the screw rotors of said pump and motor which are mounted on a common shaft are identical in pitch diameter and helix angle.

4. The apparatus of claim 3, wherein the screw rotors of said pump have a larger tip diameter and a correspondingly smaller base diameter than the screw rotors of said motor.

5. The apparatus of claim 1 in which the driving fluid outlet of said motor is in fluid communication with the inlet of said pump.

6. The apparatus of claim 1, wherein the driving fluid outlet consists of a chamber formed in the interior of the housing between said motor and said pump.

7. The apparatus of claim 6, wherein the pumped fluid inlet consists of a port opening formed in the housing wall, which port opening discharges into said chamber.

8. The apparatus of claim 1, wherein the driving fluid inlet is located near one end of the housing and the pumped fluid outlet is located near an opposite end of the housing.

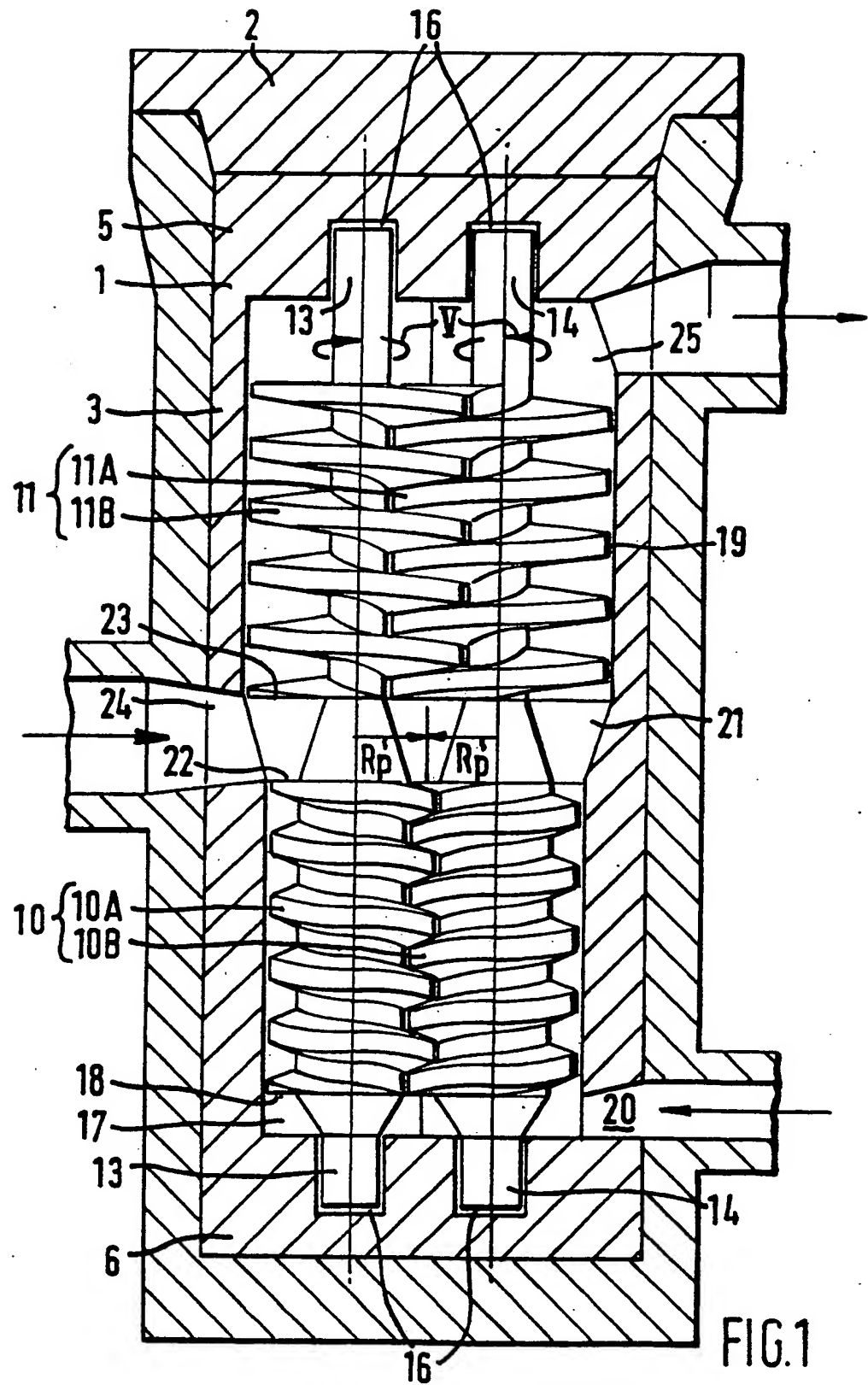
9. The apparatus of claim 1, wherein the screw rotors of said pump and motor which are mounted on common shafts are identical in diameter and helix angle.

10. The apparatus of claim 9 wherein the housing has a longitudinal axis parallel to said shafts, a side wall with a co-axial cylindrical outer surface, cross-axial upper and lower terminal walls and a cross-axial intermediate wall dividing the housing into an upper and a lower compartment, the lower compartment containing the screw rotors of said pump and the upper compartment containing the screw rotors of said motor and wherein said shafts pass through openings in said intermediate wall and are rotatably supported by bearings in the upper and lower terminal walls.

11. The apparatus of claim 10, wherein the production fluid inlet consists of an inlet port passing through the lower terminal wall of the housing and the driving fluid outlet consists of an outlet port passing through the upper terminal wall of the housing.

12. The apparatus of claim 10 or 11, wherein the production fluid outlet consists of a production fluid conduit extending through a longitudinal bore in the side wall of the housing, said bore forming a by-pass along the upper compartment.

13. The apparatus of any one of claims 10-12, wherein the driving fluid inlet consists of a driving fluid inlet port passing through the side wall of the housing into the interior of the upper compartment at a location adjacent to the intermediate wall.



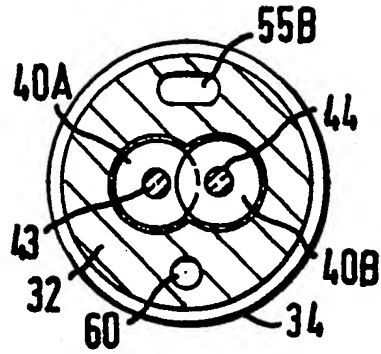


FIG. 4

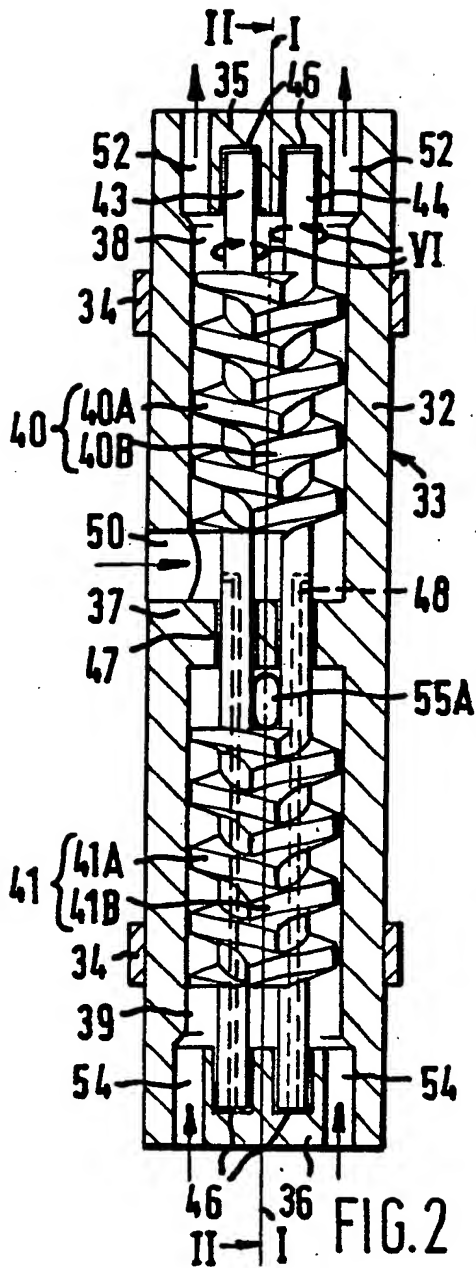


FIG. 2

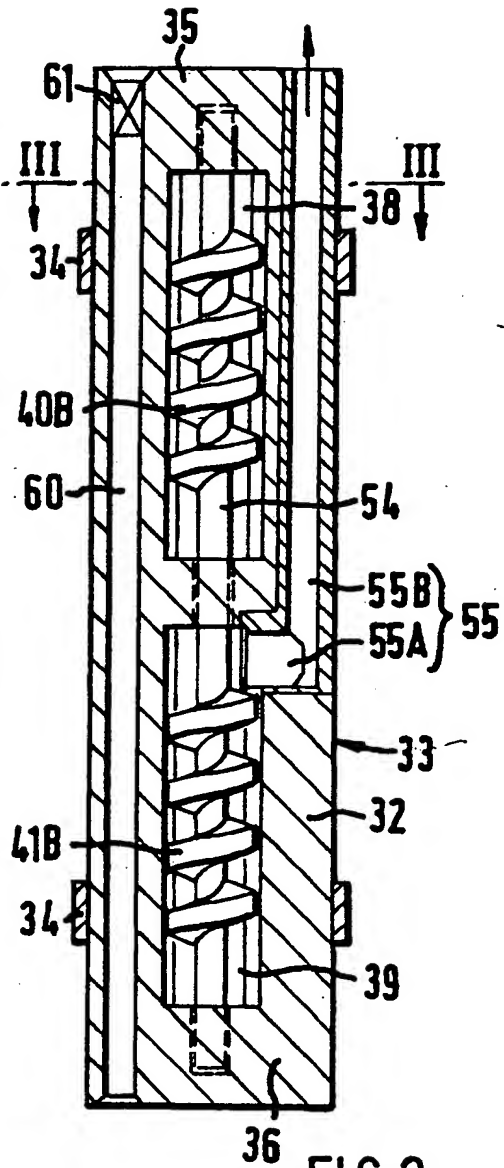


FIG. 3



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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 4)
X	US-A-1 702 838 (OLIPHANT) * Figures 2,3; page 1, line 107 - page 2, line 15; claim 7 *	1,6	F 01 C 13/04 E 21 B 43/12 F 04 C 11/00
Y	---	5,8	
Y	GB-A-2 057 058 (KOBÉ) * Figure 2 *	5,8	
A	---	11,12	
X	US-A-3 184 155 (CROOKS) * Figure 1; column 1, lines 8-15; column 2, lines 29-35; claim 1 *	1	
X	US-A-2 804 260 (NILSSON) * Figure 15; column 1, paragraph 1; column 8, line 73 - column 9, line 9; claim 12 *	1	TECHNICAL FIELDS SEARCHED (Int. Cl. 4)
A	US-A-4 386 654 (BECKER) * Abstract; figures 2,6 *	12	F 04 C 11/00 F 04 C 15/00 F 04 C 29/00 F 01 C 13/00 E 21 B 43/00
A,P	EP-A-0 155 544 (NORTON CHRISTENSEN) * Figures 3,4,8; page 6, lines 14-27; page, lines 1-12 *	5-8	
---		-/-	
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 12-12-1986	Examiner TEERLING J.H.
CATEGORY OF CITED DOCUMENTS			
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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	Page 2 CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A	US-A-2 269 189 (DOWNS) * Page 4, lines 35-39; figure 1-A *  -----	12	
			TECHNICAL FIELDS SEARCHED (Int. Cl.4)
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 12-12-1986	Examiner TEERLING J.H.
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